The Spectrum of Solar Wind Charge Exchange Emission:

Contribution to the SXRB

Hi all!
I'm sorry I can't be there with you…

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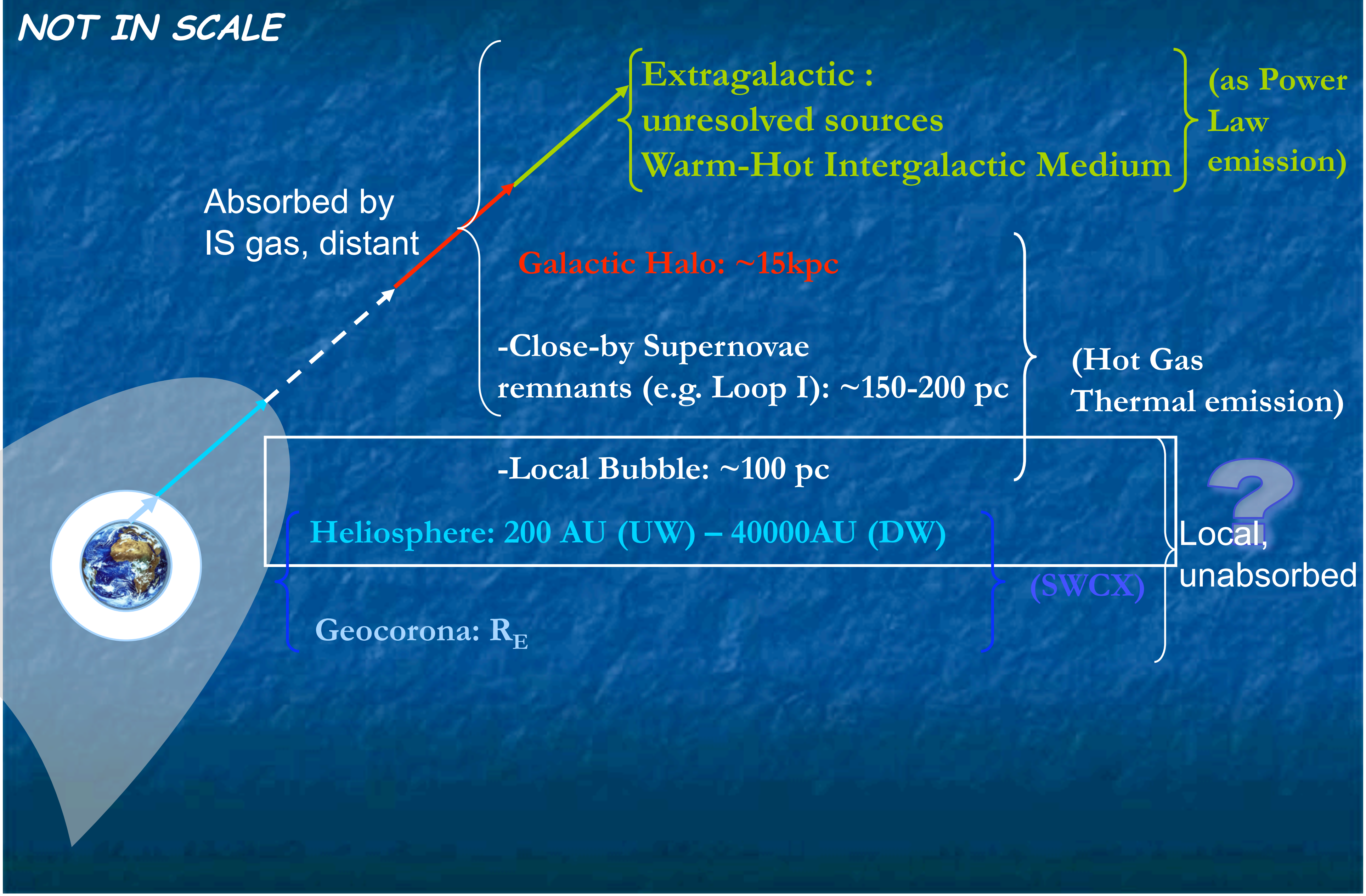
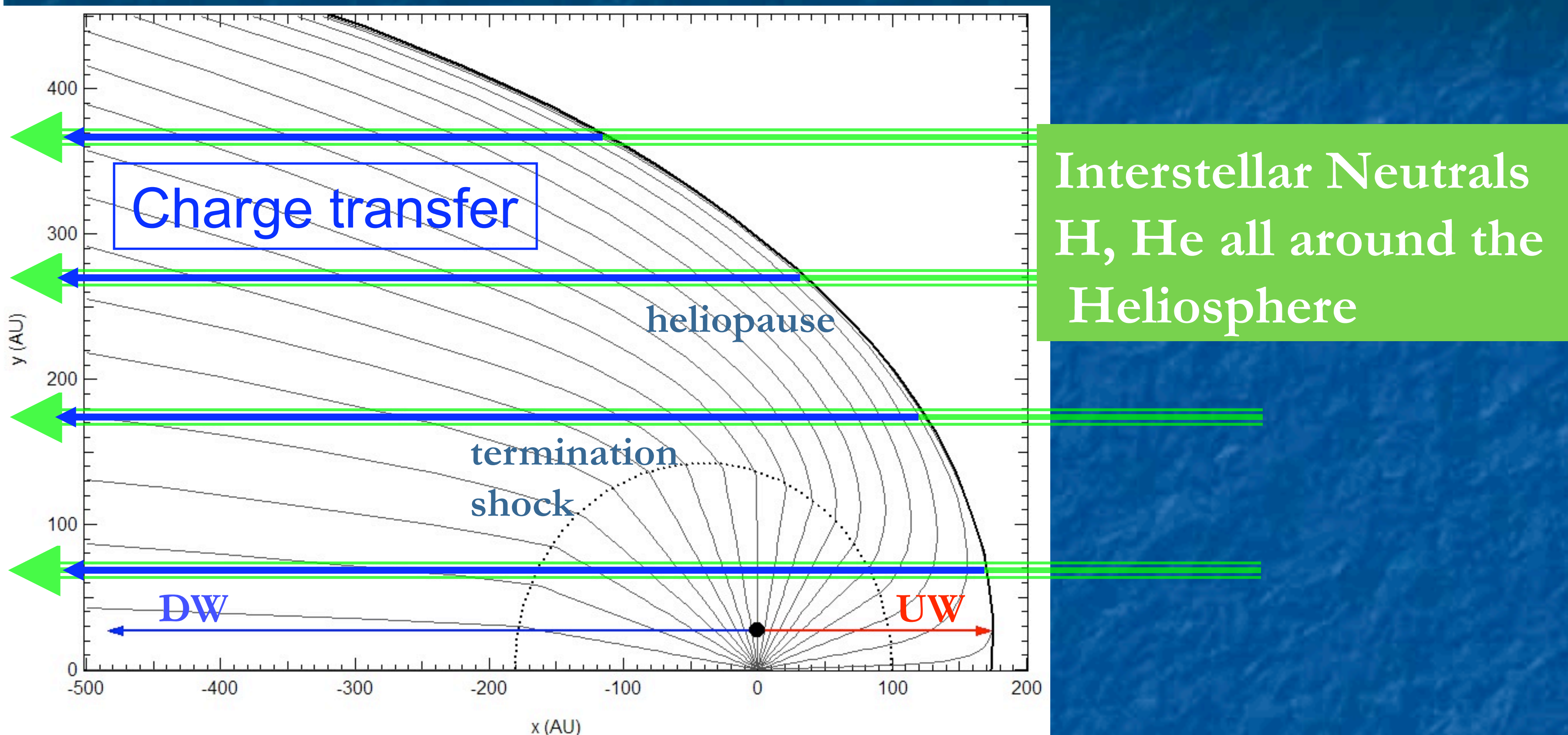
Outline

- General characteristics of heliospheric SWCX emission
  - Model description:
    - Stationnary
    - Dynamic
- Model-Data comparison (using shadowing observations)
  - ¾ keV band (Chandra, XMM, Suzaku)
  - ¼ keV band (ROSAT, Wisconsin surveys)

Contributions to the Soft X-ray Background



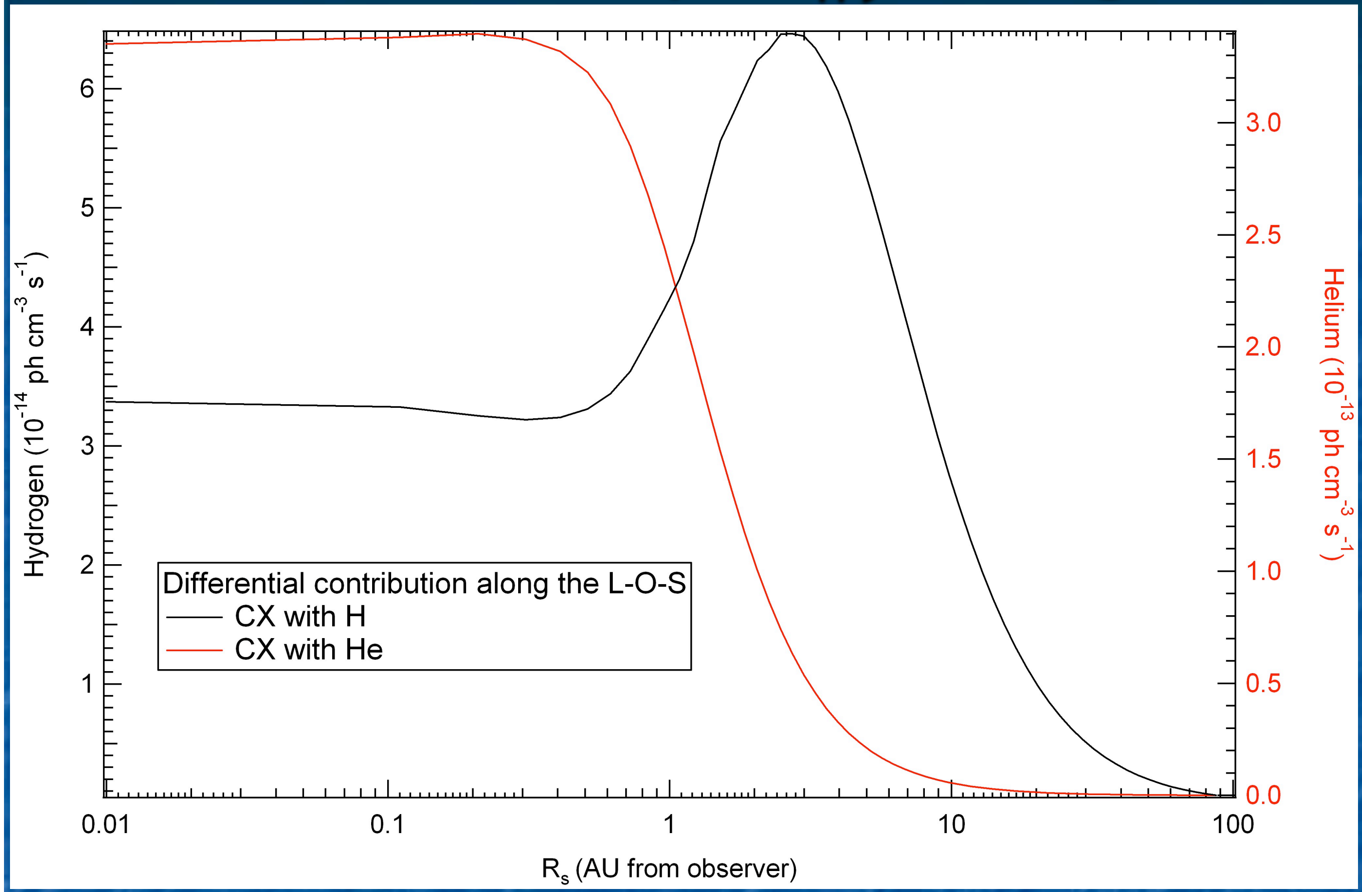
Where does the heliospheric emission end?



Along a given line-of-sight the contribution to the emission ends:

- either at the heliopause
- in the downwind direction where the particular solar ion has been entirely consumed

CX emissivity $\varepsilon_{h\nu}$ along a Line-Of-Sight



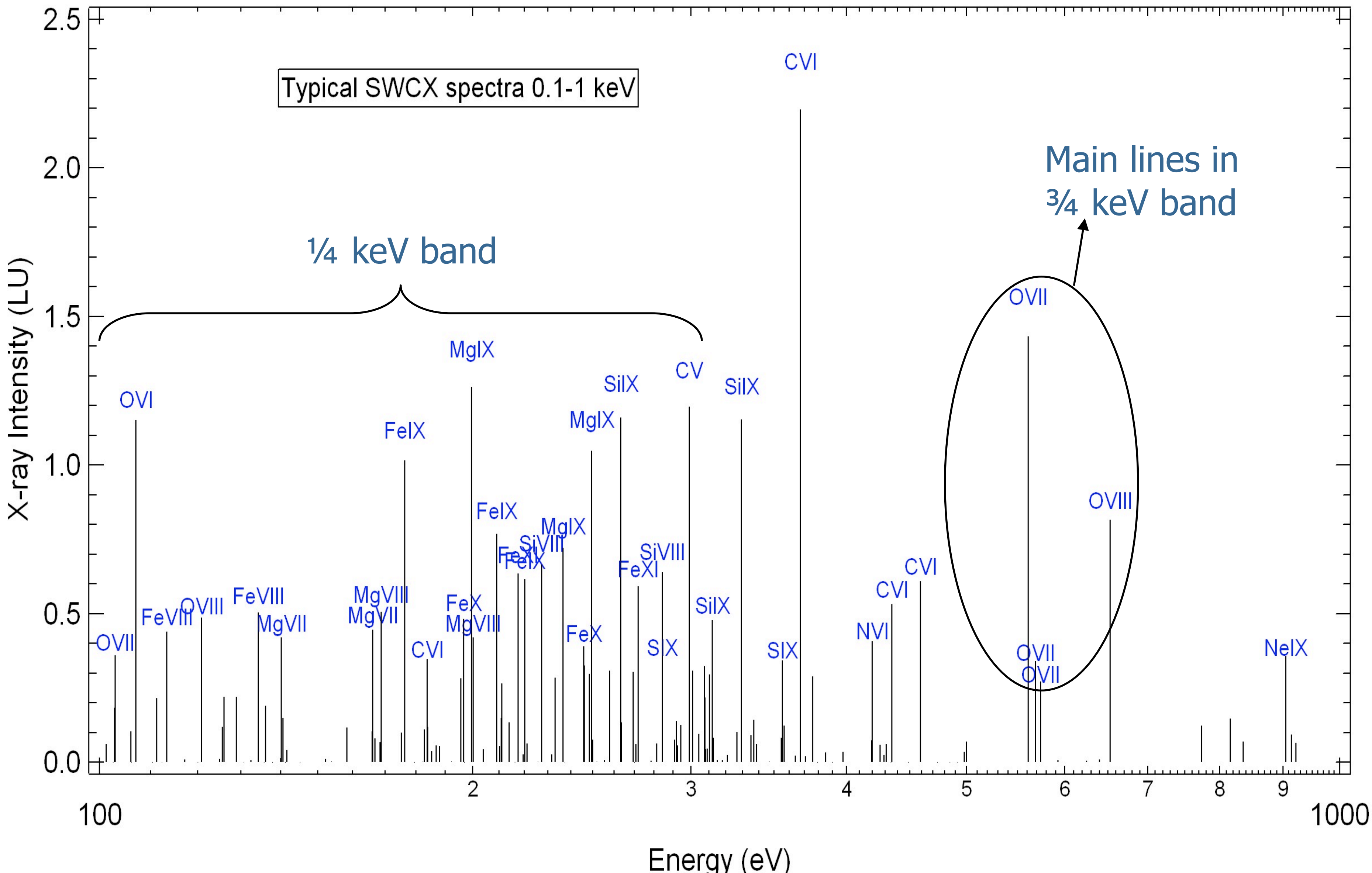
Total intensity along a L-O-S

$$I_{h\nu}(\vec{O}, L\vec{O}S) = \frac{1}{4\pi}\int_0^{\sim 100AU} \varepsilon_{h\nu}(r)\, dr$$

88% of total emission due to H in D<10 AU
98% of total emission due to He in D<5 AU

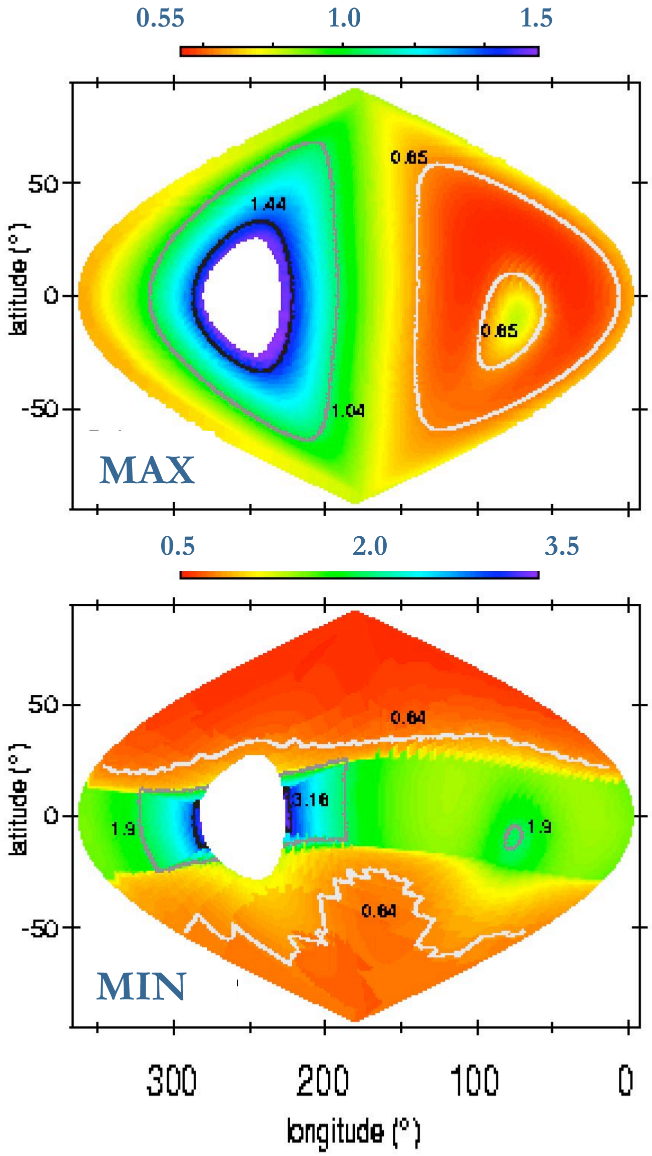
For an observer on Earth the inner Heliosphere contributes the most to the SXRB, with respect to the Heliosheath

Spectra of SWCX emission 0.1-1 keV



Computed X-ray maps: OVIII 0.65 keV

Observer at λ = 74°



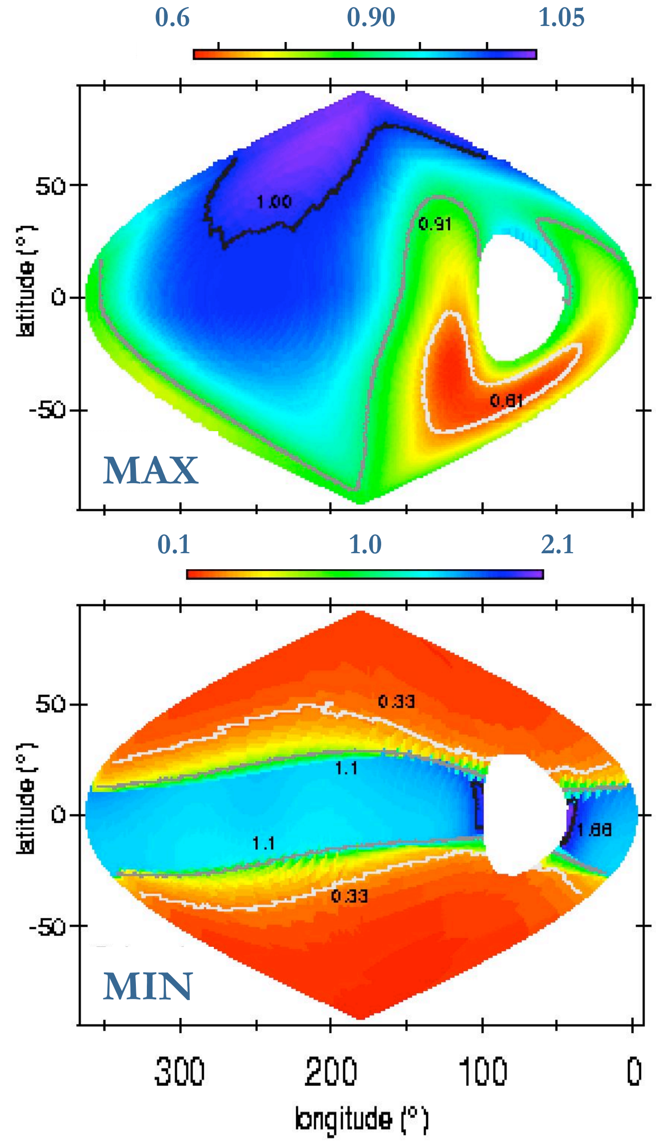
Colorscales in units of 10^{-9} erg cm^{-2} s^{-1} sr^{-1}

RED: low

BLUE: high

Koutroumpa et al., A&A 2006

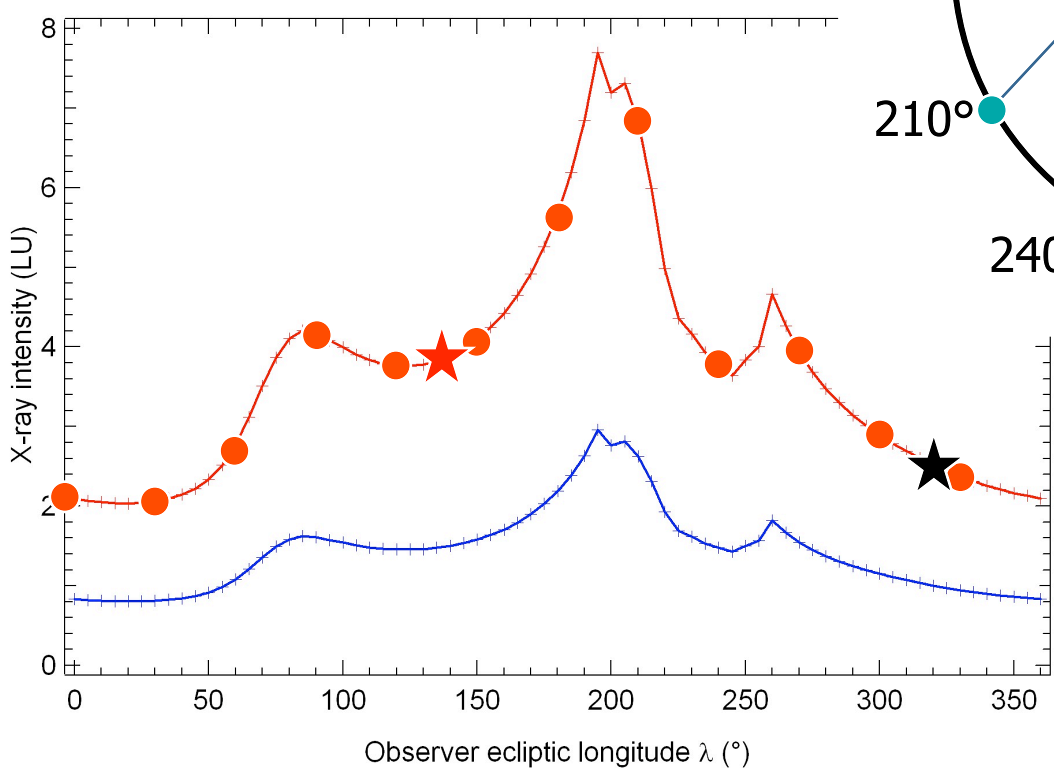
Observer at λ = 252°

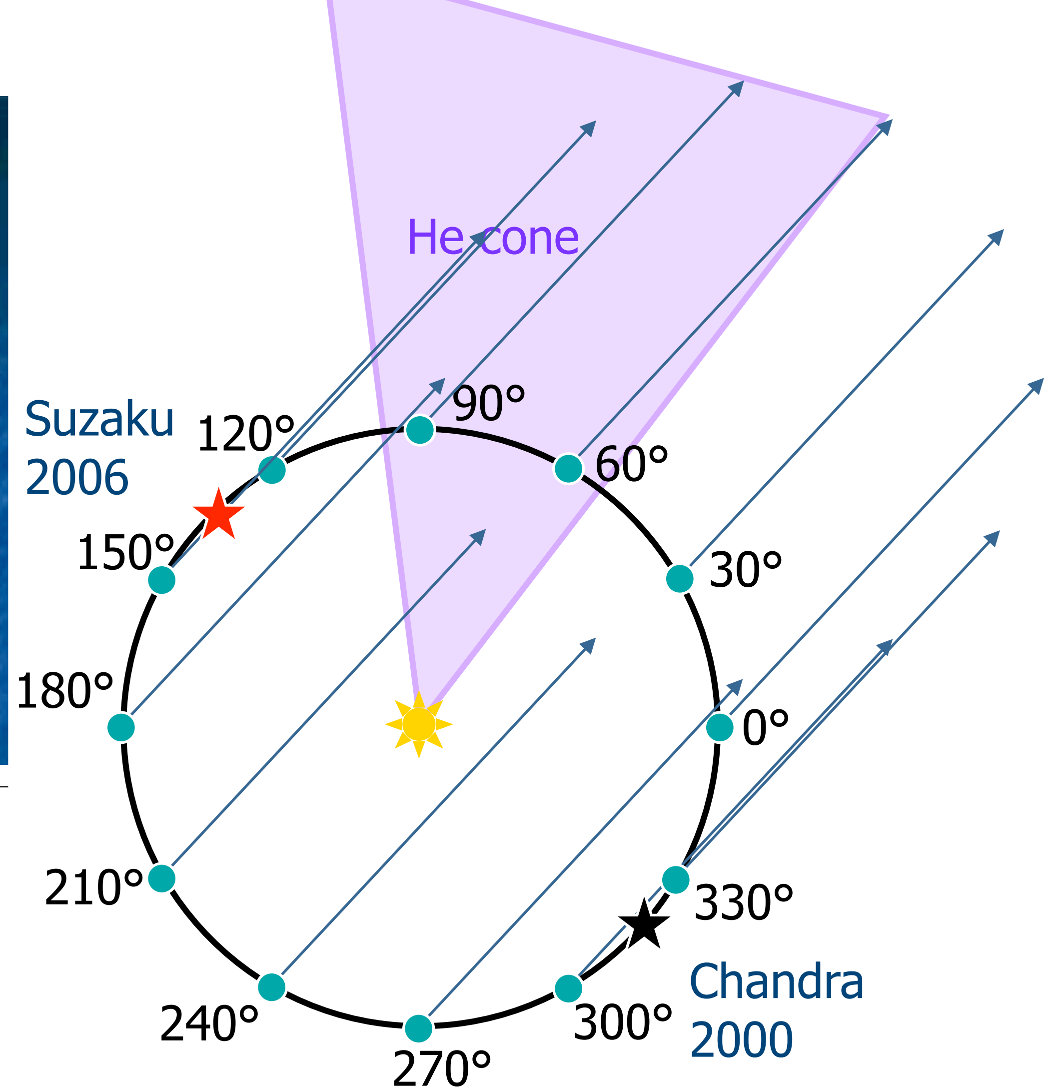


Parallax effects in SWCX emission

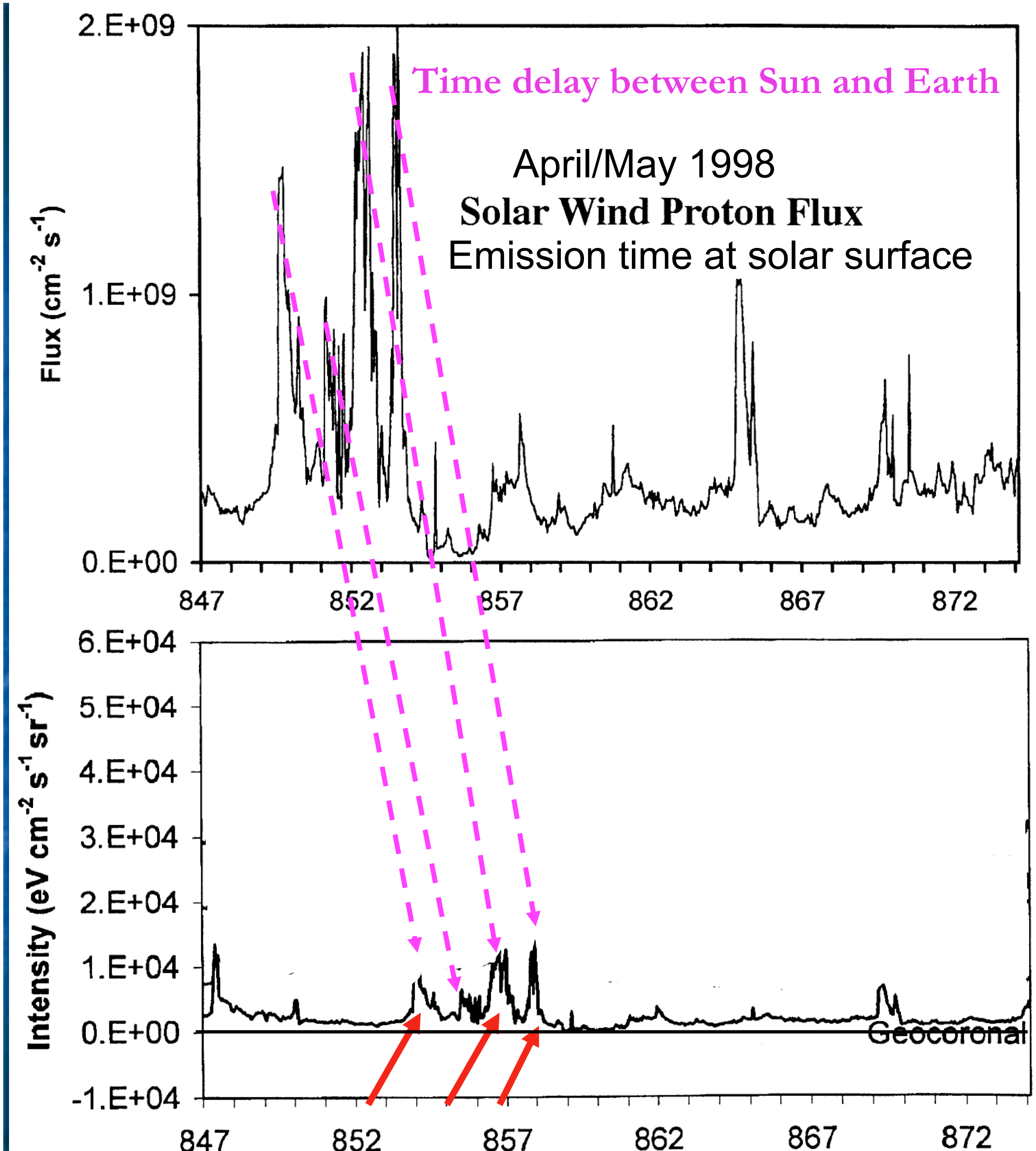
Predicted by Lallement, 2004

(calculated for the MBM 12 line of sight)





Temporal variability of the ¼ keV background: CX signature

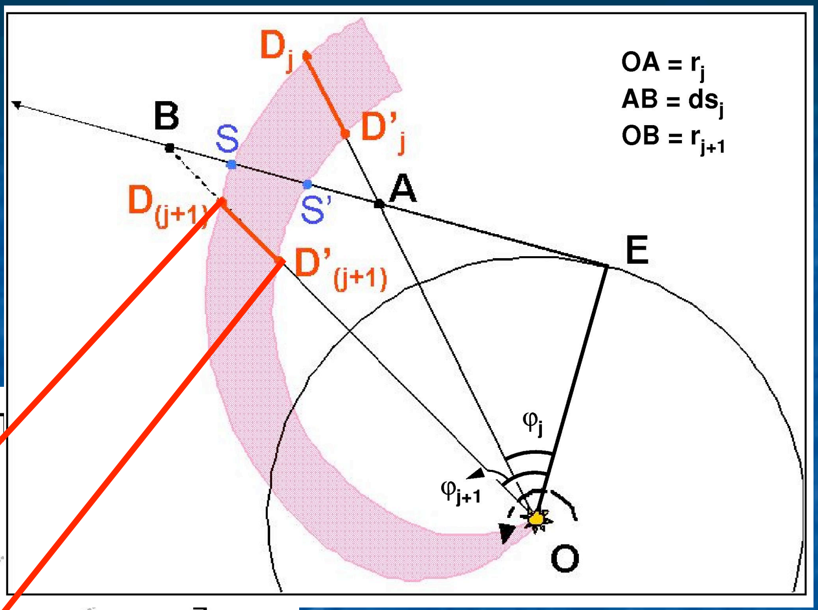


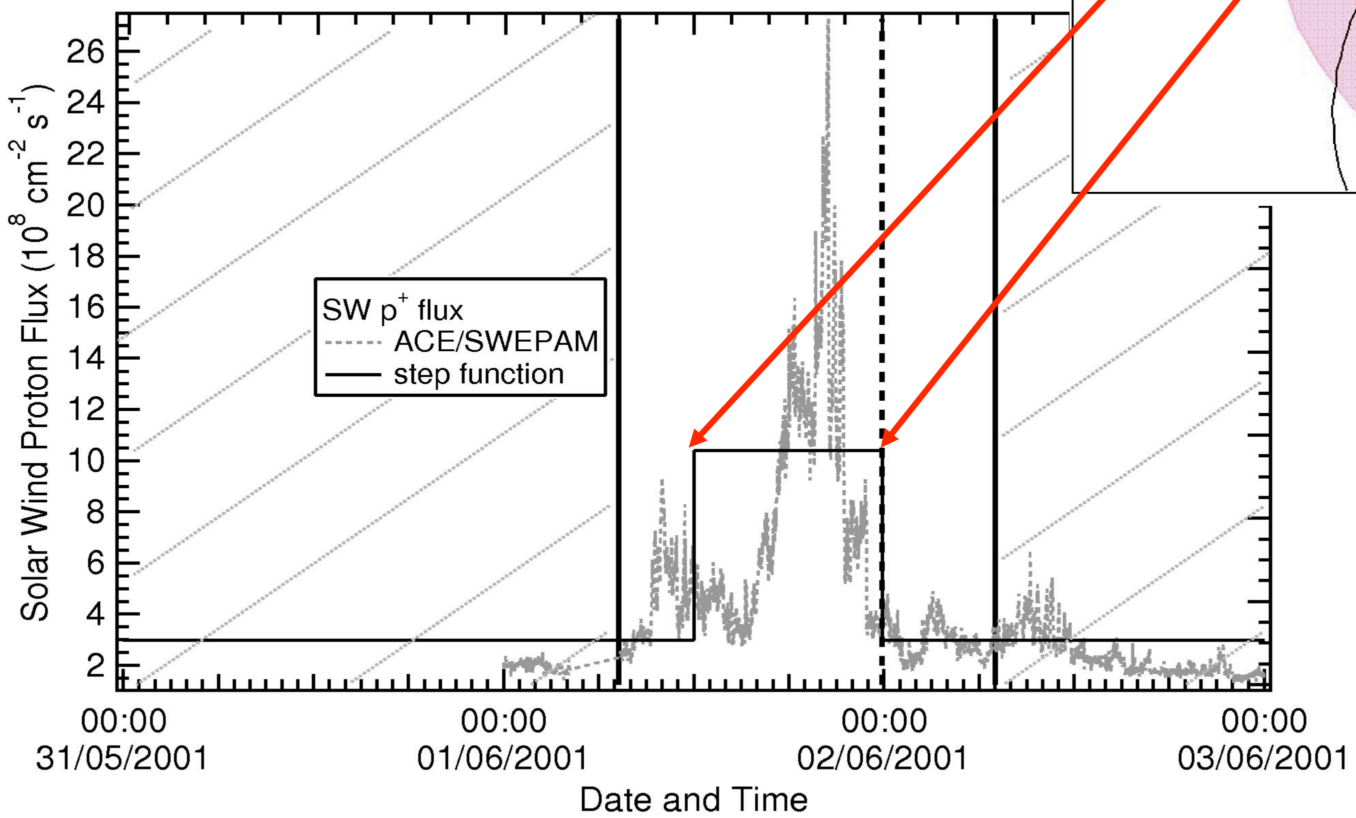
First simplified model:
Cravens et al, 2001,
J. Geophys. Res

GEOCORONA X-ray contribution to the ROSAT 0.25 keV background:
About 1/10 of the average measured background

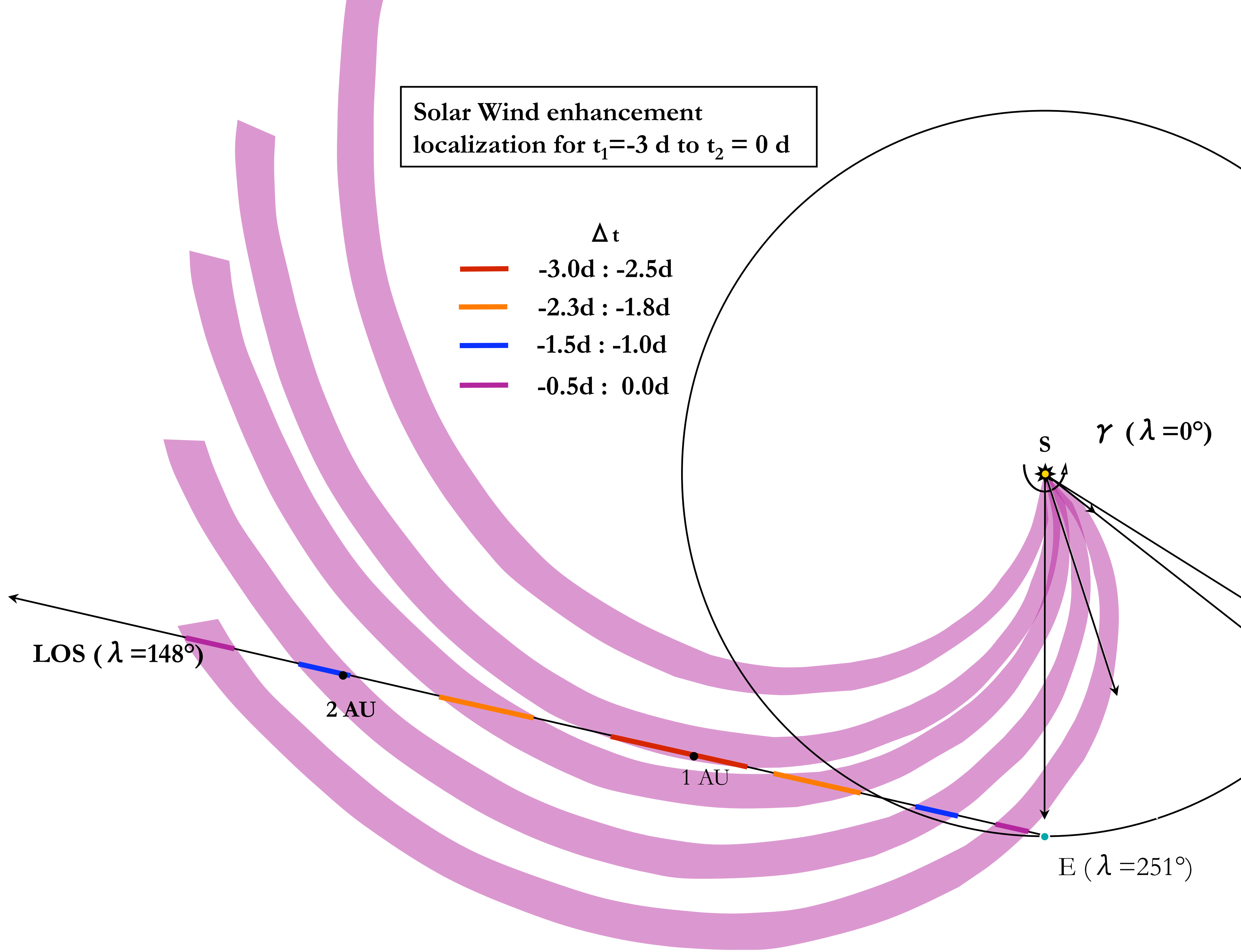
Modeling the SW variations

Spiral's width equivalent to time duration, SW enhancements modeled as step functions



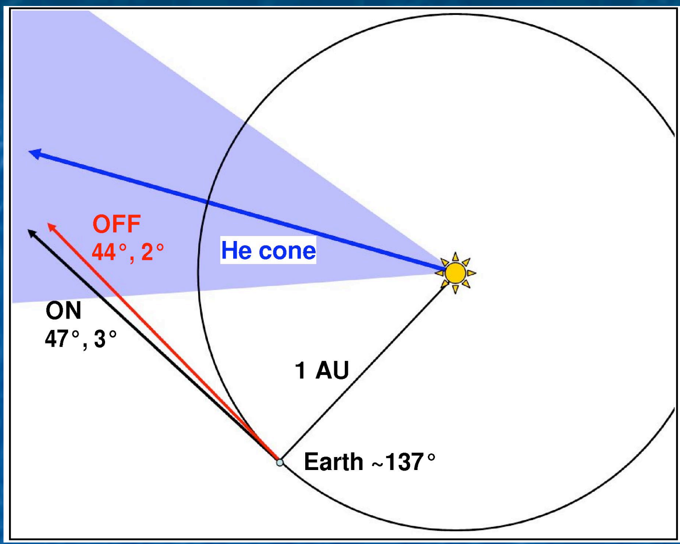


ACE, Wind database search for:
- SW proton flux &
- Heavy ion abundance variations



Solar Wind enhancement
localization for t_1=-3 d to t_2 = 0 d
Δ t
-3.0d : -2.5d
-2.3d : -1.8d
-1.5d : -1.0d
-0.5d : 0.0d
S
γ (λ =0°)
LOS (λ =148°)
2 AU
1 AU
E (λ =251°)

Smooth heliospheric lightcurves can be tricky: ex. MBM 12 (Feb. 2006, Suzaku)



-<u>Global solar activity</u>: Min, higher SWCX X-rays than Max

-<u>LOS crossing the He cone</u>: OFF-cloud exposure sees denser IP region

-<u>Local SW conditions</u>: Intense spike at end of ON-cloud exp.

Koutroumpa et al., 2007

<u>ON-CLOUD:</u>

<u>Model intensities:</u>

I (O^{6+}) = 3.56 LU

I (O^{7+}) = 0.5 LU

<u>Data (Smith et al., 2007):</u>

I (O^{6+}) = (3.34±0.26) LU

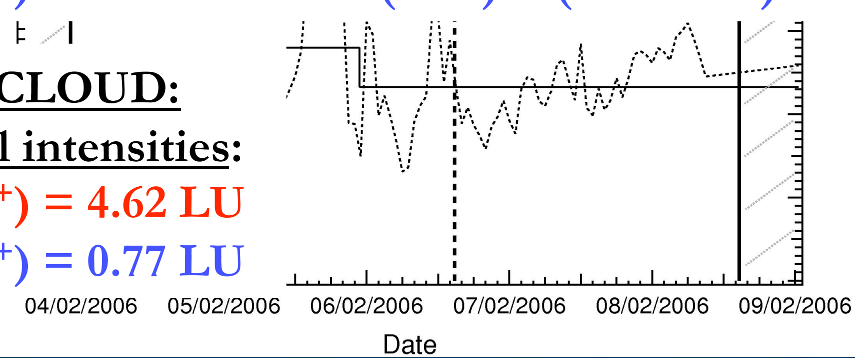
I (O^{7+}) = (0.24±0.10) LU

<u>OFF-CLOUD:</u>

<u>Model intensities:</u>

I (O^{6+}) = 4.62 LU

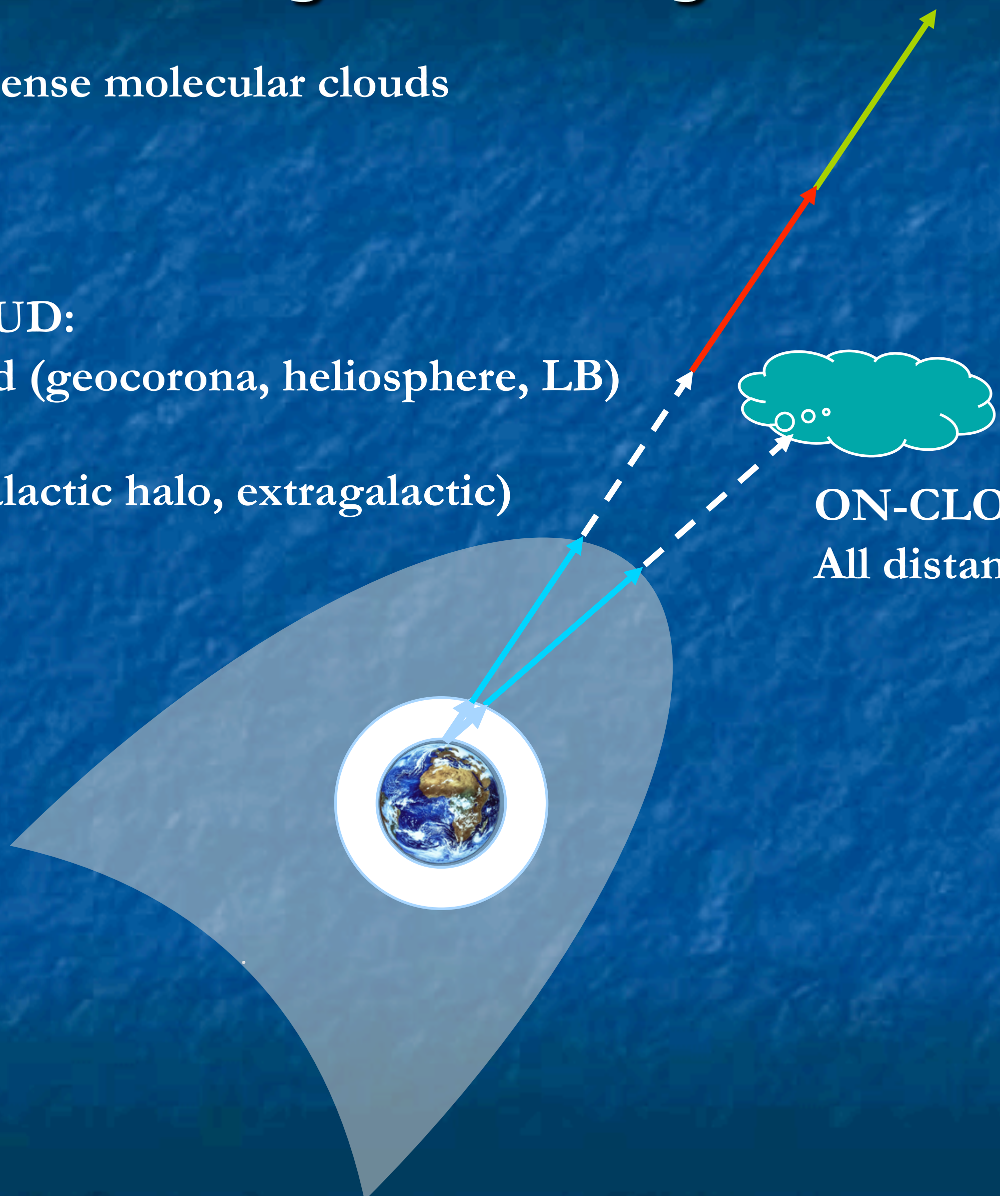
I (O^{7+}) = 0.77 LU



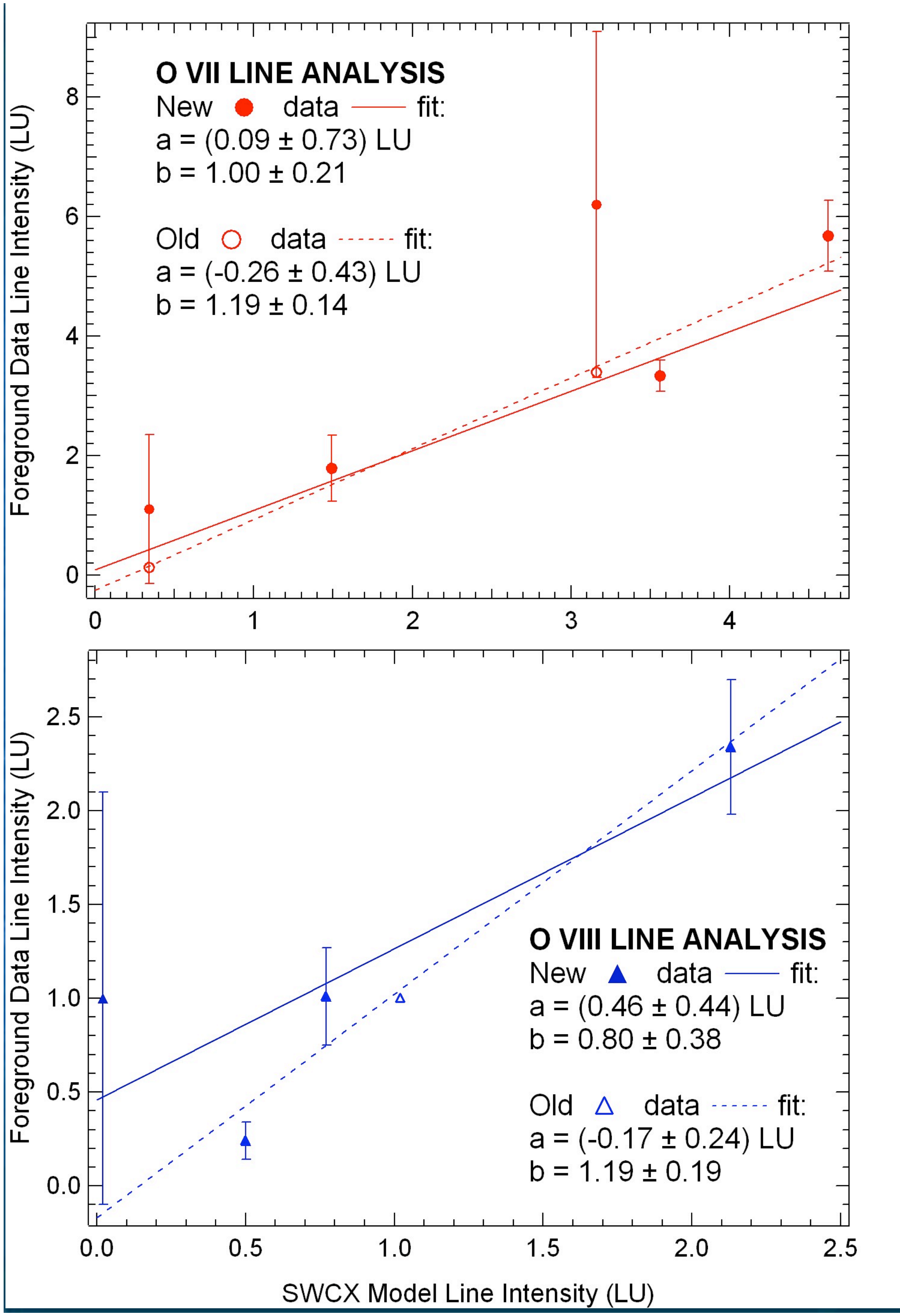
Using Shadowing observations

Targets: Dense molecular clouds

OFF-CLOUD:
Foreground (geocorona, heliosphere, LB)
+
Distant (galactic halo, extragalactic)



ON-CLOUD (ideal case):
All distant components are absorbed



SWCX Model to Unabsorbed (Local) Data Fit in ¾ keV band

SWCX model applied to 2 shadowing fields:
-MBM 12 (Chandra 2000, Suzaku 2006)
-South Galactic Filament - SGF (XMM 2002, Suzaku 2006)

-Taking into account real observation geometry
-Real-time SW conditions: max in 2000-2002 and min in 2006

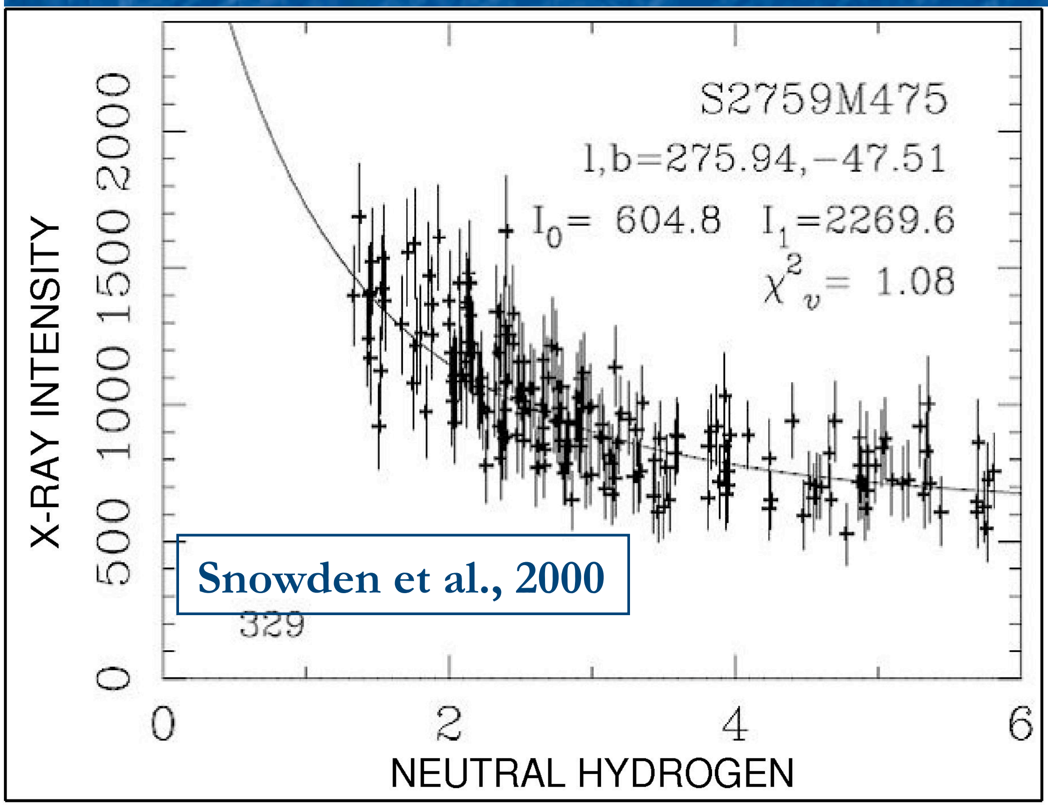
Old analysis →Koutroumpa et al., 2007
New analysis →updates from Henley et al., 2008

<u>Unabsorbed emission attributed to the Local Bubble in the ¾ keV band consistant with zero</u>:
OVII: LB I_o = (0.09 ± 0.73) LU
OVIII: LB I_o = (0.46 ±0.44) LU

Using shadowing in the ¼ keV band

soft X-ray background that does NOT anticorrelate with the IS column density

Soft X-ray shadows study: ROSAT R1+R2 (R12) data correlated with IRAS ($100\,\mu$m) data (scaled to H I column density)



X-ray intensity (10^{-6} counts s^{-1} $arcmin^{-2}$) vs H I column density N_H(10^{20} cm^{-2})

$$I_x = I_o + I_1 \times \exp\left[\sigma (N_H, T_{6.0}) \times N_H\right] + A$$

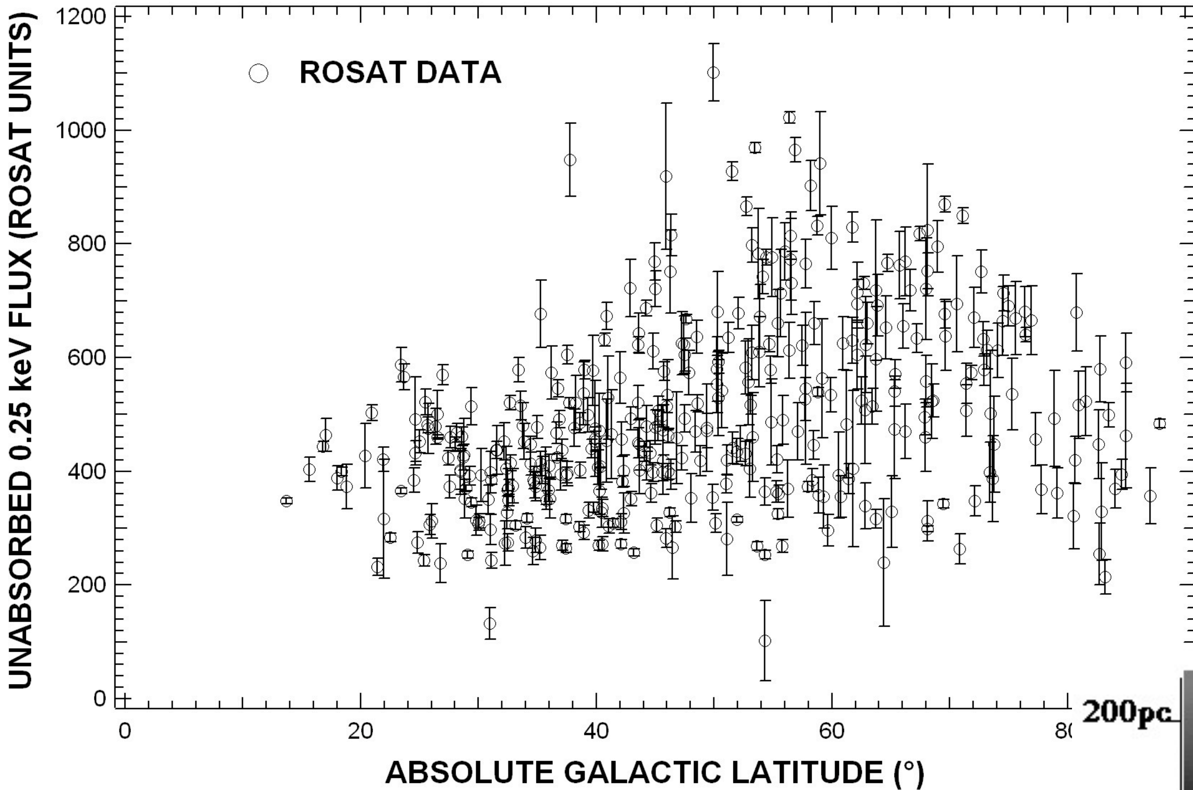
I_x : observed intensity

I_o : Foreground emission

I_1 : Halo emission

A: fixed emission for absorbed hot Halo & ExtraGalactic

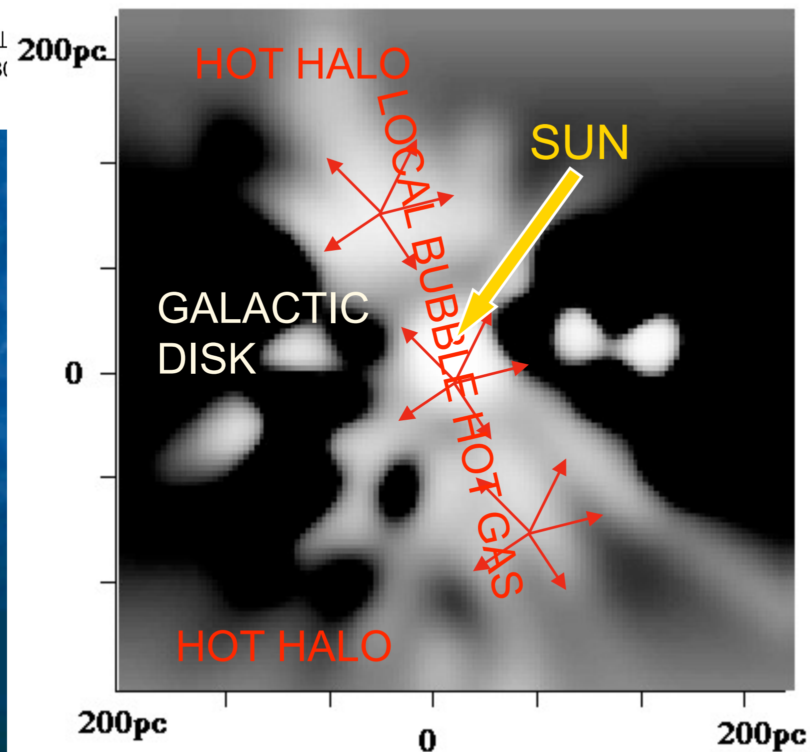
I_o : attributed to the Local Bubble

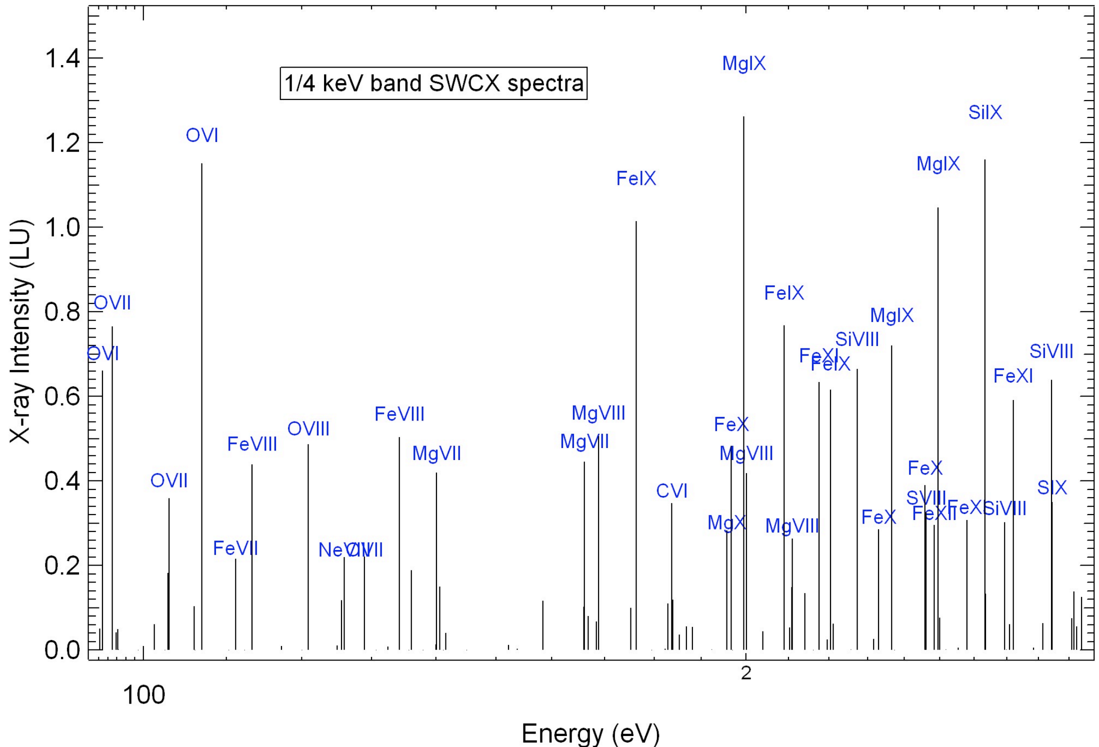


Picture 1

I_o: SOFT X-RAY FROM THE LOCAL BUBBLE INCLUDING SOLAR REGION

Higher I_o → LB more extended

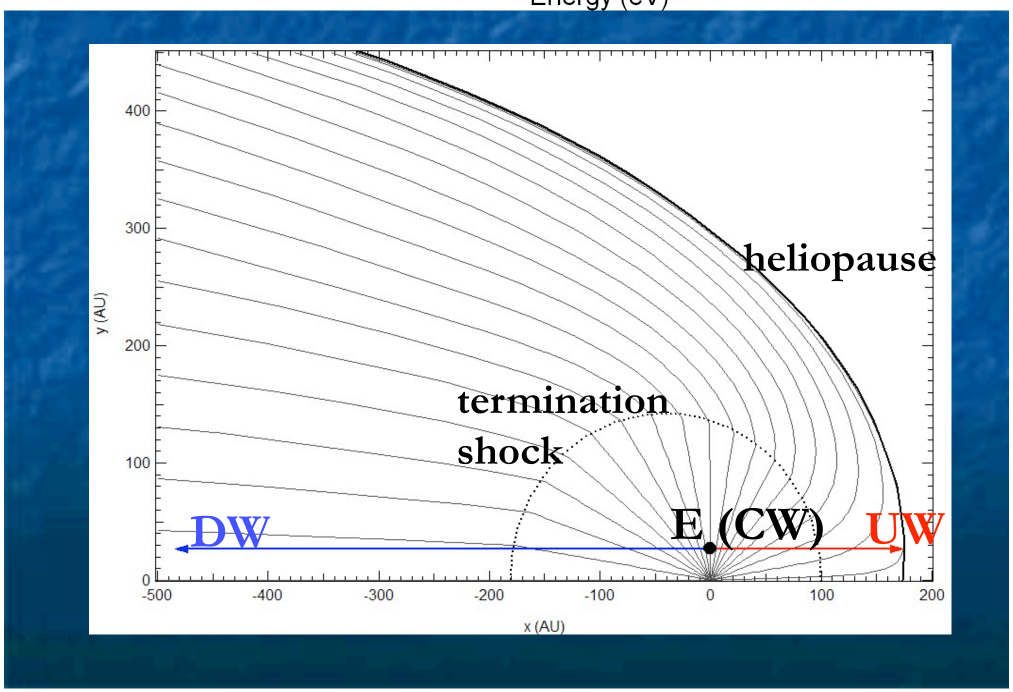


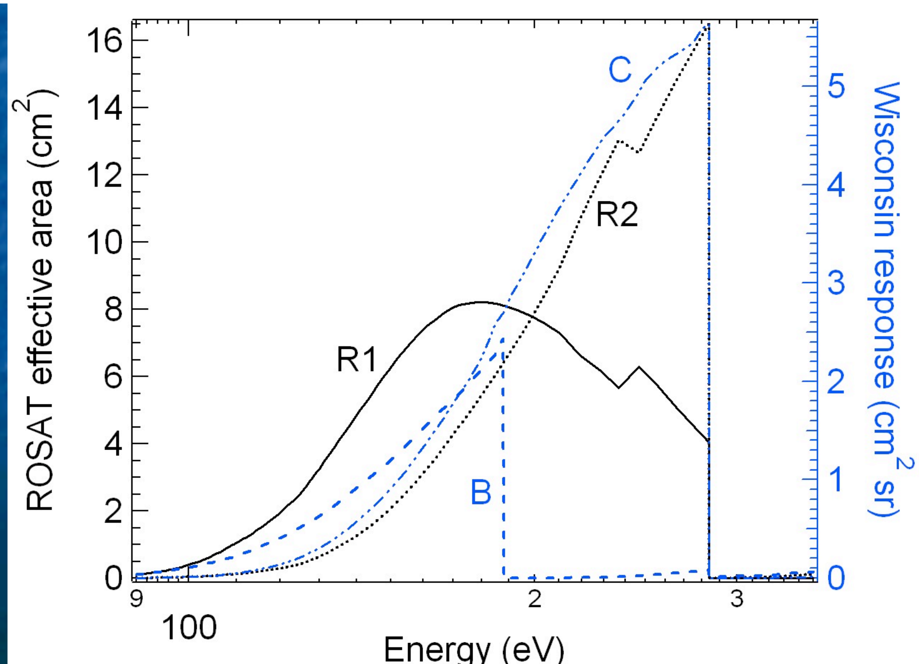


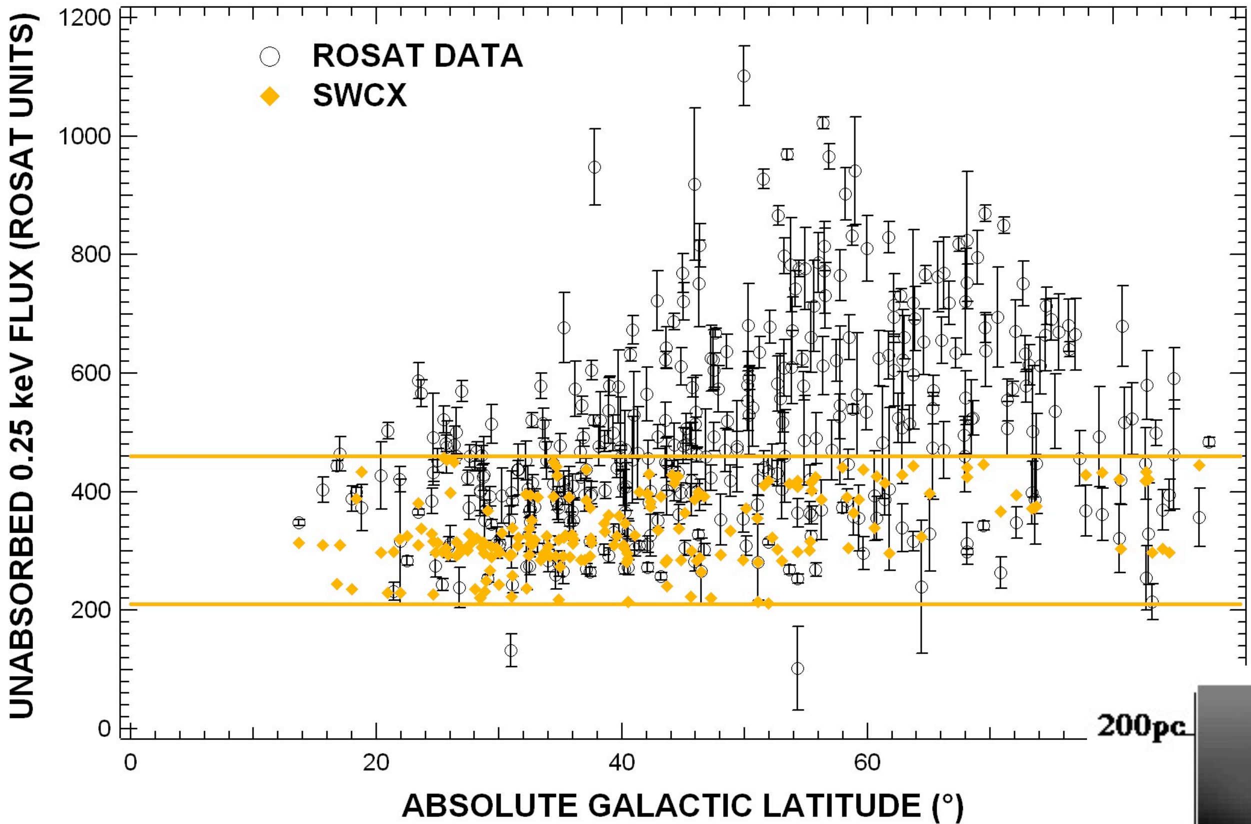
Model-Data comparison: ¼ keV

-Spectra calculated in ROSAT observation geometry

-Convolved with ROSAT R1, R2 & Wisconsin B, C band responses

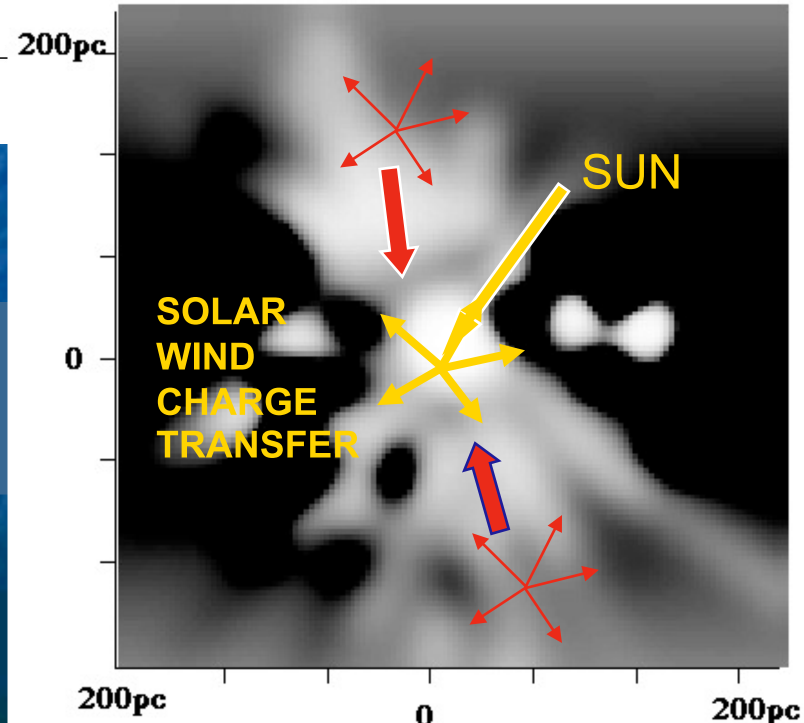






Picture 2

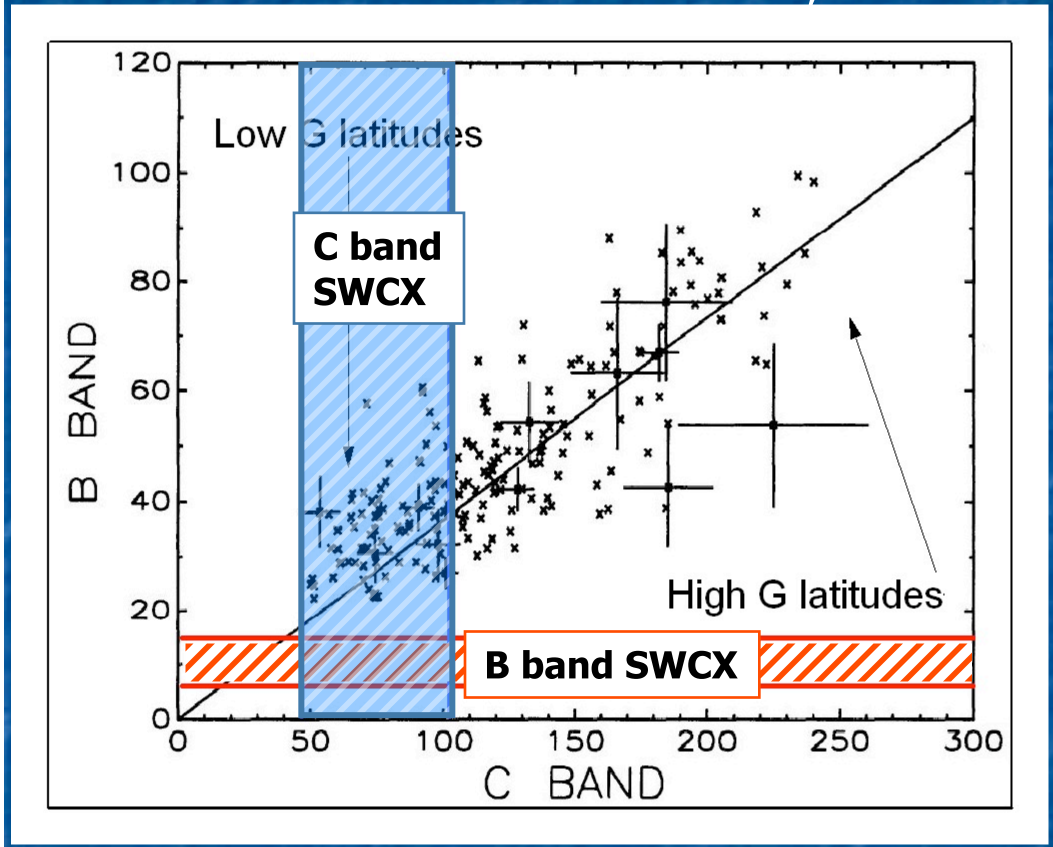
What if…



R12 EMISSION FROM LOW LATITUDES ==
SOLAR
X-RAY AT HIGH LATITUDES FROM HALO??

Comparison to Wisconsin B band

Snowden et al., 1990



-Still good agreement in low G latitudes for C band (similar to R12)

-SWCX emission not enough to account for the emission observed in the B band

There is more than SWCX in the local SXRB

BUT WHAT ?

-Can not be at too high temperature (T < 10^6 K) → SWCX must be included

-Can not be too low → OVI observational constraints

Conclusions

- ¾ keV: shadows ⇒ (almost) all the **LOCAL component is SWCX** from the Heliosphere
- ¼ keV:
  - Band ratios (R2/R1 & B/C) for the data were interpreted only in terms of hot gas plasma emission from the LB (Heliospheric SWCX was unknown & thus neglected)
  - Heliospheric **SWCX** simulations give sufficient emission in the R12 (or C) band ⇒ **could account for SXRB in the GALACTIC DISK**
  - SWCX model lower in the B band with respect to data
  - Including the heliospheric SWCX component to the data interpretation still leaves place for a '**WARM**' Local Bubble ⇒ $T<10^6$ K
- Data analysis in both (¾ & ¼ keV) bands should be revised to include SWCX